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THE EFFECTS OF 50% NITROUS OXIDE ON LARYNGEAL MASK AIRWAY CUFF PRESSURES AT 5 MINUTE INTERVALS FOR 30 MINUTES

A research project submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University

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Abstract

A STUDY TO DETERMINE THE EFFECTS OF 50% NITROUS OXIDE ON LARYNGEAL MASK AIRWAY CUFF PRESSURES AT 5 MINUTE INTERVALS FOR 30 MINUTES.

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This study tested the effects of 50% nitrous oxide and 50% oxygen had on laryngeal mask airway cuff pressures over 30 minutes. An experimental design was chosen and a sample of 30 trials were ran. The trials were ran in vitro. An intubation manikin was used to approximate clinical conditions. All cuff samples were checked by spectrometer after each trial to measure nitrous oxide absorption.

This study revealed a dramatic increase in cuff pressures due to 50% nitrous oxide exposure over 30 minutes. Using a repeated measures ANOVA, a statistical significant finding ($p < .001$) occurred.

In a clinical situation, a laryngeal mask cuff pressure as low as 25 mm Hg can cause necrosis of pharyngeal mucosa. In addition to necrosis, displacement of the airway and

rupture of the laryngeal mask airway cuff can occur. The LMA is a new adjunct to airway management that is not without inherent risks to include pharyngeal tissue necrosis. Careful monitoring of LMA cuff pressures is paramount to a safe anesthetic.

Chapter One

Introduction

Nitrous oxide is one of the oldest and most commonly used anesthetic agents. It is a weak anesthetic and the least toxic of all inhalation agents available. It is routinely used in the delivery of general anesthesia. Yet, nitrous oxide is not without potential complications.

Nitrous oxide's ability to diffuse into air cavities has been extensively studied and documented. Stanley, (1974) found that temperature, the gram molecular weight of the gas, and the gas solubility in tissue were all factors associated with nitrous oxide diffusion. He felt that the endotracheal cuff wall thickness, partial pressure differences of nitrous oxide and oxygen, and solubility were critical factors in volume increases. From his work it was reasonably easy to predict what the effects of 50% nitrous oxide administration would be on a patient with a pneumothorax. In the first 10 minutes the pneumothorax can double in size; if a 75% nitrous oxide concentration is used, the increase can be as much as four-fold. The ability

of nitrous oxide to diffuse is not limited to biological cavities. Endotracheal tubes and Swan-Ganz catheter balloons can also increase in volume and pressure due to nitrous oxide diffusion.

A new product available for airway management during anesthesia delivery is the laryngeal mask airway (LMA). The LMA bridges the gap between the face mask and the endotracheal tube. The LMA enhances the ease of anesthetic administration, as well as provides increased security of the patient airway.

The LMA consists of a tube connected to an inflatable cuff which rests in the pharyngeal perimeter (see Figure 1). The standard adult #4 LMA has a 30 cc inflatable cuff. When properly inflated, the LMA expands into place forming a low pressure seal; it also helps to protect the patient from aspiration of oral secretions. The LMA is constructed of medical grade silicone, unlike the standard endotracheal tube which is composed of polyvinyl chloride, a carbon based polymerized vinyl compound. Silicone is a synthetic rubber in which the carbon molecule has been replaced by silicone; such compounds are characterized by high resistance to temperature changes and is water resistant. Medical grade silicone has the impurities removed during manufacture to avoid allergic reactions when in contact with the body.

As with any gas filled equipment, improper use of the LMA can be hazardous. If nitrous oxide diffusion occurs

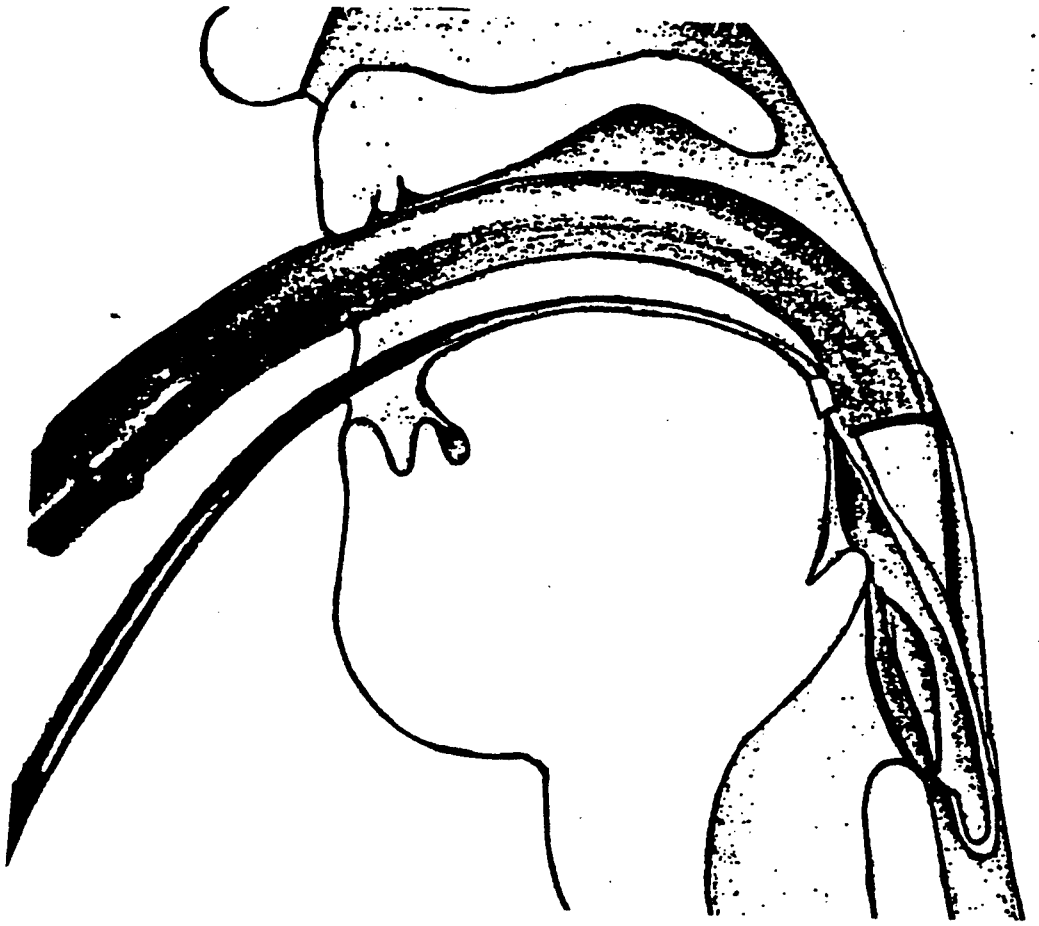


Figure 1. Correct placement of the laryngeal mask airway, with the mask tip reaching down into the base of the hypopharynx.

Note. From The Intavent Laryngeal Mask Instruction Manual by A.I.J. Brain, 1992,Tidmarsh, UK: Brain Medical Ltd (p.51).

with the laryngeal mask airway, the cuff increases in size and becomes a high pressure, high volume reservoir. This could lead to ischemia and necrosis of the laryngeal cavity as well as malposition of the laryngeal mask airway and loss of the airway intraoperatively. This study addresses the action of nitrous oxide on the cuff pressures of the LMA. The relationship between time interval, nitrous oxide concentration, and LMA cuff pressure is examined.

Statement of Purpose

The purpose of this study is to determine if there is a measurable difference in the cuff pressures of a laryngeal mask airway exposed to nitrous oxide and oxygen compared to air and oxygen over time.

Statement of the Problem

Is there a measurable difference between initial cuff pressures of the LMA and after exposure to nitrous oxide and oxygen compared to air and oxygen?

Hypothesis

There is no measurable difference between initial cuff pressures of the laryngeal mask airway after exposure to nitrous oxide and oxygen when compared to air and oxygen.

Variables

The independent variables were the nitrous oxide and oxygen trial and the oxygen and air trial. The dependent variable was the laryngeal mask airway cuff pressure.

Definition of Terms

The following definition of terms was used in this study.

Laryngeal mask airway. This airway is a non-disposable airway. It consists of a cuff that forms a seal around the inlet of the larynx and a tube to direct gases into the larynx. This allows airway control without tracheal intubation. The LMA is constructed of medical grade silicone (Brain,1992).

Nitrous oxide. Nitrous oxide (N20) is a colorless gas having a sweet taste and a pleasant odor. Its primary use is as a general anesthetic. It is also called laughing gas.

Pressure. The stress or strain exerted on a laryngeal mask airway cuff, measured in millimeters of mercury, is pressure.

Assumptions

The following assumptions were used in this study.

1. The laryngeal mask airway cuffs had no defects after initial testing.

2. The Hewlett-Packard monitoring system was correctly calibrated.

3. The anesthesia machine flow meters were correctly calibrated.

4. The cuff pressures of the laryngeal mask airways exposed to oxygen and air remained constant over time.

Limitations

The following were the limitations used in this study.

1. This study used only 2 laryngeal mask airways due to availability.

2. The study was preformed *in vitro* due to lack of research available on laryngeal mask airway exposure to nitrous oxide.

Delimitations

The following are the delimitations used in this study.

1. The nitrous oxide percentage was adjusted with the flow meter and checked with an agent analyzer.

2. All tests were performed using the same anesthesia machine.

3. All measurements were taken using the same pressure transducer.

4. All measurements were taken at exactly 5 minute intervals.

5. All cuff contents were analyzed by a spectrometer after each trial.

Conceptual Framework

Anesthesia delivery. In 1842 Crawford Williamson Long used inhalation of ether as a anesthetic agent to remove a lump from the neck of a patient. His only equipment was a towel and a can of ether. By 1847 two recorded deaths had been blamed on anesthesia due to inadequate ventilation (Wylie & Churchill-Davidson, 1984).

Inhalation general anesthesia is a safe and effective means of delivering oxygen and anesthetic agents. Over 20 million anesthetic are administered each year in the United States (Kitz & Vandam, 1990). A general anesthetic is one in which the patient is rendered unconscious. Care must be taken to maintain the airway and adequately ventilate the lungs during this type of anesthesia. Airway maintenance can be accomplished by mask, LMA, or endotracheal intubation.

Airway maintenance. Inhalation general anesthesia is a safe and effective means of delivering oxygen and anesthetic agents. Securing and maintaining an adequate airway is critical for the delivery of inhalation anesthetic agents. The loss of a patient's airway is the most common mechanism of a avoidable adverse event in anesthesia today. It

accounts for 10% of all medical indemnity claims paid (Rhee, Derlet, & Fung, 1988).

The most secure method for maintenance of a patent airway is the placement of a cuffed tube in the trachea by direct laryngoscopy with cricoid pressure. This method provides adjustment of optimal tidal volumes, addition of supplemental oxygen, and protection of the lungs from aspiration of gastric contents. Though most secure, direct laryngoscopy is not without risks. A tooth can be chipped or dislodged. The tongue or lips can be cut or nicked with the laryngoscope and esophageal or endobronchial intubation are potential problems. To achieve optimal intubation conditions, the patient must be unconscious, with skeletal muscle relaxation, and controlled sympathetic nervous responses.

For patients at low risk for gastric aspiration and short surgical procedures where muscle relaxation is not necessary, delivery of volatile anesthetics and oxygen by face mask is the optimal technique for general inhalation anesthesia. Care must be taken when maintaining an airway when using of a face mask. An oral airway is usually inserted in the oral cavity to hold the tongue up and out of the way. A jaw-thrust can also be used to help align the oral-pharyngeal pathway to preserve patency of the airway. This technique requires the provider's constant attention since the airway is never secure as with the endotracheal

tube. The face mask also requires one or both hands of the provider to correctly maintain the airway and ventilate the patient. A mask strap may be used to secure the mask on the patient's face but this technique increases the risk of facial nerve damage due to pressure and time. The use of the face mask also increases the risk of eye injury due to incorrect mask placement.

Laryngeal mask airway. In 1981, at the Royal London Hospital, Whitechapel in London, an anesthesiologist, Dr. Archie Brain, developed a device to bridge the gap between the endotracheal tube and the anesthesia mask. Brain felt that the endotracheal tube extended too far into the airway causing irritation and requiring additional drugs for placement not necessarily warranted for the surgical procedure. He also felt that the anesthesia mask was inadequate since it left a gap between the lips and nares to the opening of the larynx. Brain developed the laryngeal mask airway to rapidly overcome an obstructed airway, and yet, be simple and atraumatic to insert.

The laryngeal mask airway consists of a cuff that forms a seal around the inlet of the larynx and a tube that direct gases to the larynx. When inflated, this allows increased airway control without tracheal intubation. In addition, it frees the anesthetist's hands to perform other duties.

The LMA is inserted by trial and error. Preparation of the tube requires deflation and lubrication of the cuff.

Muscle relaxation is not deemed necessary. The patient's head and neck are placed in a normal intubation position. The mouth is opened and the LMA is inserted with the black line toward the upper lip, with the tip of the LMA pressing against the hard palate. The airway is advanced as far as possible, while using care against forcing the airway. Using excessive force could cause the cuff to fold over or wedge into the esophagus. When resistance is felt the cuff is inflated. The tube should not be held during inflation, allowing the airway to cede itself during inflation. The cuff volumes are listed below in Table 1.

Table 1

Laryngeal Mask Airway Sizes and Inflation Volume

LMA Size	Patient Weight	Maximum Cuff Volume
1	less than 65kg	4 ml
2	6.5 to 25kg	10 ml
3	25kg to small adult	25 ml
4	adult	35 ml

Nitrous oxide. This gas was first prepared by Priestly in 1772. In 1800, Sir Humphry Davy demonstrated its anesthetic properties. It was not used clinically until 1844 when Gardner Quincy Colton demonstrated its effects at Hartford, Connecticut. Horace Wells, a dentist, who was observing recognized its potential as a anesthetic agent. Some early demonstrations with nitrous oxide failed, delaying its utilization for an additional 20 years.

Nitrous oxide is the only 19th century anesthetic drug still in routine use today. In fact, nitrous oxide is the most frequently administered inhalation anesthetic. Nitrous oxide is 34 times more soluble in plasma than oxygen (Stoelting, 1991). Its use is primarily in conjunction with oxygen as a vehicle to deliver volatile inhalation agents. The solubility of nitrous oxide, relative to nitrogen, is the cause of nitrous oxide diffusion into air cavities. Atmospheric air contains approximately 78% nitrogen and 21% oxygen. Nitrous oxide diffuses down its concentration gradient very quickly, while the nitrogen diffuses out relatively slowly. This causes an expansion of the air cavity and an increase in pressure.

Fick's law of diffusion. This law states that the flux of a solute is proportional to the driving force and the area over which diffusion occurs. Simply stated, this means that molecules of gas diffuse along their own concentration gradients until they become evenly distributed through out

the entire area. The LMA cuff, having a much larger cuff that the endotracheal tube cuff, could be more prone to nitrous oxide diffusion.

Laryngopharyngeal anatomy. The lowest portion of the pharynx is the laryngopharynx, which extends distally to the hyoid bone (see Figure 2). The laryngopharynx is a common pathway for food destined for the esophagus posteriorly and inhalation gases for the larynx anteriorly. The blood supply to the pharynx consists of the ascending pharyngeal artery, the ascending palatine branch of the facial artery, the descending palatine artery, the pharyngeal branches of the maxillary arteries, and the muscular branches of the superior thyroid artery. The veins of the pharynx drain into the pterygoid plexus and the internal jugular vein. Perfusion pressure of the laryngopharynx mucosa is 25-35 mm Hg (Miller, 1990). It is this perfusion pressure that becomes a critical factor during nitrous oxide administration and laryngeal mask airway use.

Summary

The laryngeal mask airway is an improved means of delivering inhalation anesthesia when compared to the face mask, but is not without risk. If diffusion occurs when nitrous oxide is used, the cuff could expand placing increased pressure on the laryngopharynx mucosa, Ischemia, which is time and pressure related, could occur.

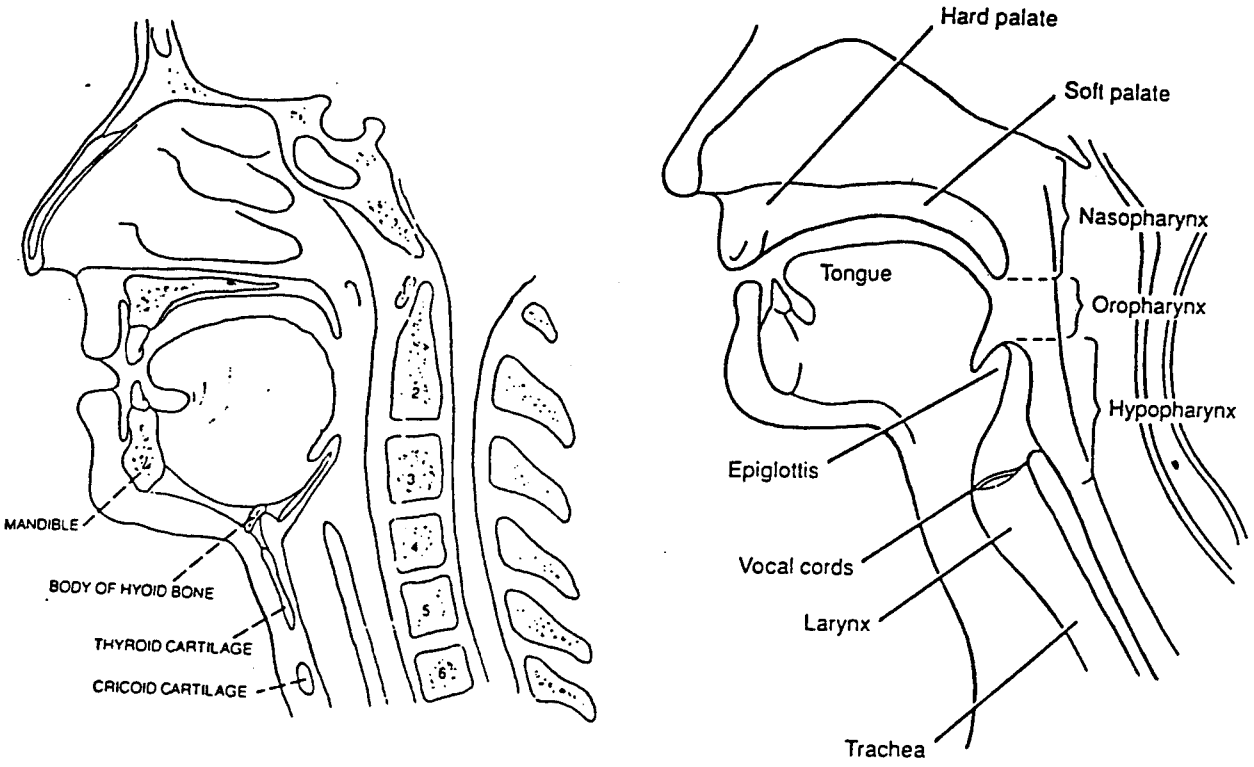


Figure 2. Anatomy of the airway.

Note. From Clinical Anesthesia by E.G.Morgan and M.S.Mikhail, 1992,Norwalk: Appleton & Lang (p.48).

The increased expansion of the cuff could also lead to migration of the laryngeal mask airway, causing malposition and intraoperative loss of airway patency, with potential for catastrophic outcomes. The purpose of this study is to examine the effects of nitrous oxide and oxygen when compared to air and oxygen on the laryngeal mask airway cuff pressures.

Chapter Two

Review of Literature

A review of the literature has identified no studies examining with the effects of nitrous oxide on the laryngeal mask cuff pressures. There have been multiple studies on the effects of nitrous oxide expansion in air cavities of the body, as well as on catheters with air-filled balloons. None of the catheters studies addressed silicone which has been used in the construction of the laryngeal mask airway.

Physiological

Nitrous oxide has a blood/gas coefficient of 0.015 and is 34 times more soluble than nitrogen. Because of nitrous oxides high degree of solubility in relation to nitrogen, nitrous oxide diffuses down a concentration gradient into closed spaces more rapidly than nitrogen can diffuse out of the respective space. This diffusion increases the pressure in the spaces which are closed to the atmosphere. If an air-filled cavity is compliant, as is a pneumothorax, it expands in size. If the cavity is non-compliant, such as a cerebral ventricle, it will cause a pressure increase (Stoelting & Miller, 1989). Enlargement of air emboli was

researched by Presson, Kirk, Hasseby, and Wagner (1991). In their study, patients were ventilated with nitrous oxide, and air bubbles were injected into the right atrium. When the bubbles were examined in the pulmonary arterioles, it was found that they had enlarged in size. The study was repeated with helium and the same effect was noted.

The ability of gas to diffuse into a closed cavity is not limited to nitrous oxide and helium. Oxygen can also diffuse down a concentration gradient but to less than 10% than that of nitrous oxide (Morgan & Mikhail, 1992). The diffusion of oxygen is insignificant when compared to that of nitrous oxide.

Endotracheal Tubes

The classic studies of the effects of nitrous oxide diffusion into endotracheal tube cuffs were performed by Stanley in the early 1970s. These experiments remain as standards in the field. Stanley (1974) exposed red rubber endotracheal tubes with latex cuffs to varying percentages of cyclopropane, nitrous oxide, and ethylene in oxygen. At various time periods, the cuffs were measured and aspirated, and the contents were analyzed using a Hewlett-Packard chromatograph. The results showed that the diffusion of anesthetic gases into the endotracheal tube cuffs were both time and concentration related. All the gases increased the endotracheal tube cuff volumes, with significant increases

in volume ($p < .001$) after 1 hour of exposure. Stanley observed that oxygen diffused down its gradient into the endotracheal tube cuff, but to a much lesser extent than anesthetic gases. The major limitation of this study was that it was conducted *in vitro*. Little effort was placed on duplicating the environment an endotracheal tube would be placed in when in use. The control temperature was 20 degrees Celsius and the concentrations of the anesthetic agents were extended beyond toxic levels.

The second study addressing nitrous oxide absorption into endotracheal tube cuffs was conducted by Stanley, Kawamuraq, and Graves (1974). This was also an *in vitro* study. Latex cuffs of endotracheal tubes were exposed to nitrous oxide in various concentrations over time, with significant ($p < .001$) increases in cuff size after 1 hour. This experiment had minimal application to clinical practice due to the hypoxic concentrations of nitrous oxide used and the prolonged exposure times 1, 12, 16, 24, 36, and 48 hours. Thus, Stanley's first two studies demonstrated that nitrous oxide diffused into latex endotracheal tube cuffs *in vitro*.

The third study by Stanley (1975) was an *in vivo* study. In this study a broad sample of clinically available endotracheal tubes were tested with a 60% nitrous oxide and 40% oxygen concentration. The gas obtained from the cuffs of the endotracheal tubes was analyzed using a Hewlett-

Packard chromatograph. A standardized intravenous induction and maintenance regime was used for all patients. The results revealed a significant increase ($p < .001$) in cuff size. The chromatograph demonstrated that 76-88% of the measured volume of the cuffs was nitrous oxide. These three studies firmly established that nitrous oxide diffused into endotracheal tube cuffs.

Diffusion of nitrous oxide into endotracheal tube cuffs was not a benign problem. Mosby, Schelkun, and Vincent (1988) reported several case studies, citing that a 60% nitrous oxide and 40% oxygen mixture can lead to rupture of a low pressure, high volume, endotracheal tube cuffs. The rupture of the cuffs required the surgery to stop and emergent extubation and re-intubation of patients.

In addition to over-inflation of the endotracheal tube cuff due to nitrous oxide, deflation can also occur. Partridge (1988) noted that intubated patients receiving inhalation anesthesia with nitrous oxide, when taken to the intensive care units, frequently presented with symptoms of endotracheal tube cuff leaks after several hours. On examination it was noted that the cuffs of the endotracheal tubes were intact. The nitrous oxide had diffused down its concentration gradient, leaving the cuffs partially deflated.

Tracheal Damage

Changes in the tracheal mucosa occurred due to increased endotracheal tube cuff pressures. In a study by Mathias and Wedley (1974), standard Portex cuffs were compared against Portex low pressure cuffs for tracheal mucosa changes. All patients were intubated and positive pressure ventilated for 15 hours. After extubation, all patients were examined using fiberoptic endoscopy equipment to determine if tracheal or subglottic damage had occurred. Mathias concluded that multiple factors had contributed to tracheal damage. Those factors included: incorrect endotracheal tube size relative to the trachea, movement of the endotracheal tube while the patients were intubated, duration of the endotracheal intubation, endotracheal tube material, effects of steroid use on tracheal mucosa, and generalized vascular stability of the patients. The primary cause of tracheal damage, Mathias felt, was due to increased endotracheal tube cuff pressures. It should be mentioned that all the patients in the Mathais study received nitrous oxide. Mathias noted that tracheal damage was both time and pressure related. Increases in endotracheal tube cuff pressures above capillary perfusion pressures for short periods of time produced minimal or no tracheal damage.

Laryngeal Mask Airways

Airway difficulties account for 32% of all malpractice

claims, and are the most common cause of brain damage and death under anesthesia, according to the American Society of Anesthesiologists' Committees on Professional Liability. The LMA was developed by Brain over a seven year span, and in 1988 it became available for commercial use. The LMA was developed as a substitute for the face mask. It provided a safer and easier means of managing airways when compared to the face mask. It should be emphasized that it was not a substitute for an endotracheal tube. The LMA, which is reusable and autoclavable, is constructed of medical grade silicone. This substance was selected over latex rubber to avoid the latex allergy problem.

The LMA consists of a oval cuff, which is the mask, attached to a tube through which inhalation gases are delivered. Inflation cuff volumes vary according to the size of airway used. The Intavent Laryngeal Mask Instruction Manual states that over-inflation of the cuff can cause the LMA to slide up and out of the pharynx. It also states that over-inflation can cause premature wear on the airway cuff.

Several anesthesia providers have described problems with the LMA in letters to the editor. Collier (1991) reported that nitrous oxide diffuses into the LMA cuff, elevating intracuff pressures as high as 142 mm Hg over 20-40 min: this can dislodge the device. After a 30 minute exposure to nitrous oxide Lumb (1992) reported a mean rise

in cuff pressures of 30 mm Hg. Collier recommended monitoring cuff pressures if nitrous oxide is used during procedures lasting longer that 1 hour. Laryngeal mask cuff pressure problem managed by withdrawing about 25% of the volume from the cuff, or by using a similar nitrous oxide and oxygen mixture to inflate the cuff.

Summary

After reviewing the literature, no studies were found that paralleled this study. The concept of nitrous oxide diffusion into endotracheal tube cuffs was firmly established by Stanley's work. The link between endotracheal tube cuff pressures and tracheal damage was demonstrated by Mathias. Finally, the importance of proper inflation pressures with the laryngeal mask airway was addressed in Brain's instruction manual.

Chapter Three

Methodology

Research Design

This study employed an experimental design to compare laryngeal mask cuff pressures after exposure to nitrous oxide and oxygen compared to oxygen and air over a 30 minute time period. The laryngeal masks were chosen at random and assigned to the respective test groups.

Procedure

A random drawing was used to chose the laryngeal mask airway. A coin toss was used to divide the airways into two groups. Due to the limited number of laryngeal mask airways, after each trial the airway was returned to the pool of available airways. For each group 15 trials were conducted.

Group I. This group of laryngeal mask airways was the experimental group. These LMAs were placed in intubation manikins to approximate *in vivo* conditions. The cuffs were then inflated with recommended volumes of room air and the

pressures were measured with a Hewlett-Packard pressure transducer. The airways were connected to an anesthesia ventilator; a 50% nitrous oxide and 50% oxygen concentration, tidal volume of 1000 ml., and a rate of 10 breaths per minute was initiated. Cuff pressures were measured at 5 minute intervals for 30 minutes. Two 1-liter reservoir bags were used to stimulate the lungs. After each trial the laryngeal mask airway cuff contents were analyzed by Critikon spectrometer.

Group II. This group of laryngeal mask airways was the control group. These laryngeal mask airways were treated the same as the experimental group, except they were exposed to 50% air and 50% oxygen when placed on the anesthesia ventilator.

To help limit extraneous variables the room temperature was controlled at 21 degrees Celsius for all trials. In addition, the same anesthesia ventilator, spectrometer, and transducer were used in all trials.

Instrumentation

The transducer used in this study was an Hewlett-Packard Component Monitoring System. It was connected to TRANSPAC II ™ monitoring kit manufactured by Abbott Laboratories of North Chicago, Illinois. The transducer was zeroed per the Hewlett-Packard reference guide prior to each trial. The Hewlett-Packard Component Monitoring System has

a accuracy of plus or minus 1%. The pressure transducer measures in millimeters of mercury.

After each trial the contents of the laryngeal mask airway cuffs were analyzed by a POET II ™ spectrometer manufactured by Criticare Systems, Inc., Waukesha, Wisconsin. The Criticare System has an accuracy of plus or minus 5% by volume tested. The results were in percentages and whole integers.

Data analysis

Statistical analysis for the pressure readings was performed by a repeat measures ANOVA. Cuff pressures of the control group versus cuff pressures of the experimental group were analyzed repeated measures analysis of covariance. The initial cuff pressures served as the covariate. A p value $< .05$ was considered statistically significant. The software used in this study was SYSTAT, particularly the DATA, STATS and MGHL modules.

Chapter Four

Results

Sample

The sample consisted of 30 trials of LMA exposure to inhalation gases. The control group of 15 trials was exposed to a 50% oxygen and 50% air mixture. The remaining 15 trials were exposed to a 50% nitrous oxide and a 50% oxygen mixture. Two LMAs were used for all the trials and were randomly assigned to a trial by the toss of a coin.

The pressure readings over time were analyzed by a repeated measures ANOVA. This method takes into account any accidental differences in the two groups at the start and adjusts the other measurements accordingly (Polit & Hungler, 1987). The results of the ANOVA testing are presented in Table 2.

The Between Groups effect is a compilation of all cuff pressures of a group obtained across all time increments, and compares the means of the control group against the means of the nitrous group. The between Group effect tests the hypothesis that the group means, over all times, are equal (Ho:u1 =u2). This produced a p value < .001.

Table 2

ANOVA for Mean Cuff Pressures with/without Nitrous Oxide

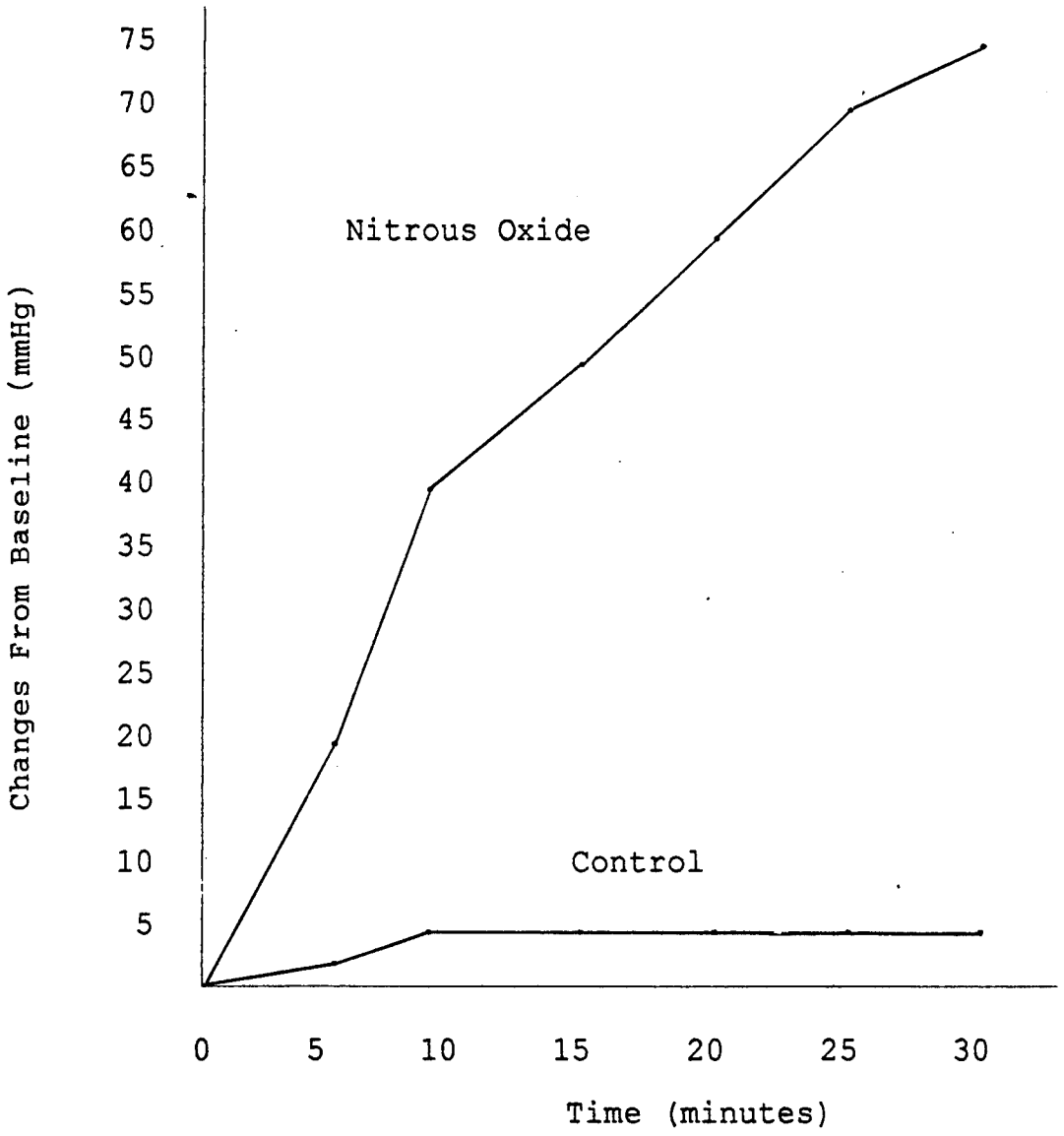
Source	Sum of Sqs	df	Mean Sq	F-ratio	p
Between					
Group	113703.20	1	113703.20	290.017	<.001
Error	10977.60	28	392.057		
Within					
Time	16269.933	5	3253.987	353.475	<.001
Time x Grp	12509.267	5	2501.853	271.772	<.001
Error	1288.800	140	9.206		

Note. $p < .05$ is significant

The Within-Time effect tests the null hypothesis that the means across both groups, at each 5-min interval, are equal (Ho: u1 = u2 = u3 = u4 = u5 = u6). This test produced a p value < .001. However, this result is not of particular interest. We are interested in the interaction effect, Time x Group. The Interaction Effect tests the hypothesis that the pattern of change over time is the same for both groups. This produced a p value < .001.

The dramatic increase in LMA cuff pressures can best be illustrated graphically in (see Figure 3). The mean pressure increases for the experimental and control group are both illustrated. Note that the control group is essentially unchanged.

Time and Group Interaction



Comparison of mean changes from baseline in the nitrous oxide and control groups.

Chapter Five

Discussion

Overview

This study was conducted to determine if a 50% concentration of nitrous oxide diffused into a laryngeal mask airway. The study consisted of 15 control trials with 50% air and 50% oxygen and 15 sample trials with 50% nitrous oxide and 50% oxygen. Pressure measurements were taken at 5 minute intervals for 30 minutes. At the end of 30 minutes, all cuff samples were analyzed by spectrometer.

The hypothesis of this study was: there was no measurable difference in laryngeal mask airway cuff pressures exposed to 50% nitrous oxide and 50% oxygen measured at 5 minute intervals for 30 minutes. The statistical analysis of the results revealed that the mean laryngeal mask airway cuff pressures between the control and nitrous oxide groups measured over all times were not equal with $p < .001$. The average increase in laryngeal mask airway cuff pressures for Group 1 (experimental) was 72.73 mm Hg over 30 minutes.

The average increase in cuff pressures for Group 2 (control) was 4.4 mm Hg over 30 minutes. The results of this study demonstrated significant differences at each time interval; therefore, the null hypothesis was rejected.

After analyzing the contents of the laryngeal mask airway cuffs, it was found that Group 1 contained an average of 32.2% nitrous oxide and 21.2% oxygen after 30 minutes of exposure. It was also noted that Group 2 showed diffusion of oxygen down it's concentration gradient with a average increase to 32.2% of oxygen. The pressure increase is this group was 4 mm Hg which was insignificant after 30 minutes.

Comparison to Previous Studies

There were no studies that investigated the effect of nitrous oxide on laryngeal mask airway cuff pressures. Stanley (1974) found that endotracheal tube cuffs exposed to nitrous oxide had significant increases in pressures measured at 1 hour. Mathias and Wedley (1974), in an *in vitro* study, measured cuff pressures of endotracheal tubes exposed to 66% nitrous oxide for up to 6 hours. Results revealed significant increases in endotracheal tube cuff pressures.

The results of this study seem to parallel the endotracheal tube studies of previous investigators.

Limitations

A limitation of this study that it was an *in vitro* study. It consisted of a laryngeal mask airway inserted into a manikin and exposed to anesthesia gases. It was not possible to duplicate actual patient conditions for LMA use. Therefore, it is not possible to generalize the results to a patient population without an *in vivo* study.

Difficulties with the Study

Several unexpected problems were noted with this study. One of the main problems was nitrous oxide pollution between control and sample trials. The manikin absorbed nitrous oxide during the sample trials and diffused into the laryngeal mask airway cuffs during several of the control trials. The polluted trials were identified by spectrometer; therefore, these trials were excluded from the study.

`Another problem noted with this study was the limited number of laryngeal mask airways available for this study. Since only 2 #4 airways were available they were chosen at random for each trial.

Recommendations for Future Studies

This study was conducted *in vitro* using a intubation manikin. The results of a *in vivo* study with the laryngeal mask airway and nitrous oxide exposure would be very

meaningful. Another recommendation would be to test different concentrations of nitrous oxide for longer periods to determine the time required for nitrous oxide to reach an equilibrium.

Summary

This study was conducted to determine if nitrous oxide would diffuse into the cuff of the laryngeal mask airway. A strong correlation was demonstrated for nitrous oxide diffusing into the laryngeal mask airway cuffs and increasing the cuff pressures. The results from this study revealed a dramatic increase in cuff pressures due to a 50% nitrous oxide exposure over 30 minutes with *in vivo* conditions. In a clinical situation, with a pressure as low as 25 mm Hg, necrosis of pharyngeal mucosa can occur. In addition to necrosis, displacement of the airway and rupture of the laryngeal mask airway cuff can occur. Care must always be exercised by the anesthesia provider to provide safe and effective care to the patients entrusted to them.

References

References

Brain, A. I. J. (1992). The Intravent Laryngeal Mask. Tidmarsh, UK: The Old Forge.

Collier, C. (1991). A hazard with the laryngeal mask airway (letter). Anesthesia Intensive Care, 19, 301.

Kitz, J. R., & Vandam, L. D. (1990). Scope of modern anesthesia practice. In R. D. Miller (ed.)., Anesthesia, 3-23. New York: Livingston Churchill.

Lumb, A. B., Wrigley, M. W. (1992). The effect of nitrous oxide on laryngeal mask cuff pressure. Anesthesia, 47, 320-323.

Mathias, D. B., & Wedley, J. R. (1974). The effects of cuffed endotracheal tubes on the tracheal wall. British Journal of Anaesthesia, 46, 846.

Miller, R. D. (1990). Anesthesia (3rd ed.). New York: Churchill Livingstone.

Morgan, E. G., & Mikhail, M. S. (1992). Clinical Anesthesiology Norwalk, CT: Appleton & Lange.

Mosby, E. L., Schelkun, P. M., & Vincent, S. K. (1988). Nitrous oxide use and endotracheal tube rupture. Anesthesia Progress, 35, 14-16.

Partridge, B. L. (1988). Nitrous oxide and endotracheal cuff leaks. Anesthesiology, 68, 167-168.

Polit, D. F., & Hungler, B. P. (1987). Nursing research, principles and methods (3rd. ed). Philadelphia: Lippincott.

Presson, R. G., Kirk, K. R., Haselby, K. A., & Wagner, W. W. (1991). Effect of ventilation with soluble and diffusion on the size of air emboli. Journal of Applied Physiology, 70, 1068-1074.

Rhee, K. J., Derlet, R. W., & Fung, D. L. (1988). Evaluating anatomical factors effecting endotracheal intubation. Journal of Emergency Medicine, 209-211.

Stanley, T. H. (1974). Effects of anesthetic gases on endotracheal tube cuff gas volumes., Anesthesia and Analgesia, 53, 481-482.

Stanley, T. H., Kawamura, R., & Graves, C. (1974). Effects of nitrous oxide on volume and pressure of endotracheal tube cuffs., Anesthesiology, 41, 256-261.

Stanley, T. H., & Liul, W. S. (1975). Tracheostomy and endotracheal tube cuff volume and pressure changes during thoracic operations. Annals of Thoracic Surgery, 20, 144-151.

Stoelting, R. K., & Miller, R. D. (1989). Basics of Anesthesia. New York: Churchill Livingstone.

Stoelting, R. K., (1991). Pharmacology & Physiology in Anesthetic Practice (2nd. ed). Philadelphia: Lippincott.

Wylie, W. D., & Churchill-Davidson, H. C. (1984). A Practice of Anaesthesia (5th. ed). Aylesbury, UK: Lloyd-Luke

Appendix A

Appendix A

Group I Raw Data

Inital Pressures	5 min	10 min	15 min	20 min	25 min	30min
100	101	102	103	103	104	104
132	132	133	133	134	134	134
164	164	165	164	164	164	164
142	142	142	142	142	142	142
94	94	96	97	97	98	98
101	103	104	105	107	108	108
88	81	82	84	85	86	87
61	63	64	66	67	68	69
86	86	87	88	89	90	91
107	107	108	108	109	109	110
108	110	111	112	112	112	113
90	93	94	94	95	95	95
100	100	101	102	103	103	104
102	102	103	104	105	106	107
96	97	98	99	100	100	101

Laryngeal mask cuff pressures in the air and oxygen group

Note: Measured in millimeters of mercury

Appendix B

Appendix B

Group II Raw Data

Inital Pressure	5 min	10 min	15 min	20 min	25 min	30 min
120	130	139	162	171	179	185
128	151	167	179	188	192	196
120	122	144	161	172	180	185
92	122	140	155	167	173	179
109	139	158	172	183	191	196
114	129	145	154	159	162	163
124	151	179	198	210	216	223
99	128	147	160	172	179	185
114	134	150	159	167	172	179
106	132	146	155	165	169	175
98	134	150	163	173	180	186
102	134	146	159	165	172	179
112	128	134	150	160	162	174
110	129	140	152	161	167	173
109	124	144	155	171	179	182

Laryngeal mask cuff pressures in the nitrous oxide and oxygen group

Note: Measured in millimeters of mercury

Vita

Robert M. Plouzek was born on November 28, 1952, in Crete, Nebraska and is an American citizen. He is a graduate from Dorchester High School, Dorchester, Nebraska in 1970. He received his Bachelor of Science in Nursing from the University of Northern Colorado, Greeley, Colorado in 1990 and subsequently practiced in Columbia, Missouri at Boone Hospital Center. He entered the Air Force Nurse Corps in 1986. In 1992, Captain Plouzek returned to school in the Department of Nurse Anesthesia, School of Allied Health Professions, Virginia Commonwealth University. He is married, with one child, and remains on active duty.